are *the conservatives*, scrupulously maintaining the ancient landmarks. It differs from the one extolled by their venerated preceptor, the one to which they have been accustomed, and in the use of which experience has given them expertness. Long companionship produces partiality, and perhaps some little modification of their own may have given them the feelings of paternity. It has answered their purpose, for with it they have accomplished delivery safely; and if, in some instances, they have wounded the integuments or fractured the cranium; or if they have been compelled to resort to the perforator, in cases where the forceps was indicated, they will console themselves with the reflection that it was an inevitable destiny—a fault of nature, and not a defect of art.

In conclusion, I must observe that I am by no means pertinacious for the precise model of the instrument presented in the illustration; for it is not improbable that experience may suggest modifications of it, which will improve its adaptability, and yet retain its essential principles. All I ask is, a careful and candid examination of those principles.

Art. VII.—*Histological Researches on the Development, Nature, and Function of Epithelial Structures.* By W. J. Burnett, M. D. (Read before the Boston Society for Natural History, Aug. 1, 1849.)

The study of epithelial and epidermic structures was pursued most faithfully and successfully in the years 1835–36, by Purkinje, Valentin, and Henle. To these investigators and able physiologists belong the refinement of the quite crude notions of these structures entertained by the earlier anatomists. This portion of general and minute anatomy received at that time, both by these men and their coadjutors, such a thorough analysis, that later inquirers have been content to follow in their paths without entering upon the many portions of this field of inquiry hitherto unexplored.

It is for this reason that we find in the general works and text-books of anatomy and physiology a succinct account of these tissues taken for the most part from the writings of these men. Their higher relations, however, to all or nearly all the more important functions of life have been, although the most interesting, but lightly discussed; and the paucity of thorough observations in this direction must have been felt by every student of minute anatomy.

From continual microscopical examinations and investigations of the various tissues of the economy, the importance of this structure has been repeatedly impressed upon my mind. In common circumstances, the difficulties of such investigations are not easily met; and it was from the fine opportunity afforded me by the presence in this city of epidemic cholera, that I was induced to follow out these inquiries.

While making a somewhat extended series of microscopical analyses of the well-known *rice-water* dejections from patients affected with this disease, in order to arrive at either positive or negative results as to the importance of such analyses towards determining its cause, the immense quantities of epithelial structure continually in the field of observation was a pressing invitation to examine carefully its structure.

This epithelium, the immense quantities of which give the dull-white opacity or "rice-water" character to these dejections, appears to be removed still attached to the *basement membrane,* in quite sizeable flakes, and in a condition far more delicate and uninjured than could have been brought about by the gentlest and most accomplished manipulations of the anatomist.

Inquiries of this kind are of importance in two points of view. 1st. As elucidating the development and nature of this tissue, considered as a structure of the animal economy. 2d. As illustrating, in a very definite manner, the origin, development, and real nature of cells considered as the primordia of all organized forms.

I need not here point out what others before me have done, either upon this structure or upon the general doctrines of cells involved in the following pages, but shall take up the subject as it was investigated, authors being credited as known portions of it pass in review.*

Epithelial structure, it matters not where it is found, is always essentially the same—and, in brief, is composed of individual, non-organizable cells, attached to a primary membrane, which last is itself attached to the tissue to which the epithelium belongs.

This arrangement is quite prominent and easily seen upon the tubes of the body, and although not capable of an equally satisfactory demonstration, yet most probably the epidermis (the external continuation of this epithelium) is thus arranged upon a primary or *basement membrane.* The localities of epithelium are summarily the following, viz., the skin; the alimentary canal, and its appendices, even to their minutest ramifications of tubes; serous and synovial cavities; the heart and blood-vessels; the lymphatic glands, and those connected with the reproductive system (mammæ and testes).

* For the principal works on this subject, the reader is especially referred to the following:—

Purkinje et Valentin—"De Phenomeno Generali et Fundamentali Motus Vibratorii continui in Membranis Animalium." Breslau, 1835.

Schwann—Mikrokopische Untersuch. 1839: p. 85.

Müller—"Elements of Physiology." Translated by Baly: vol. ii.

Henle—"Traité D'Anatomie Générale." Trad. par Jourdan. Paris, 1843: vol. i. p. 225.

Valentin—Art. "Flimmerbewegung," in Wagner's Handwörterbuch der Physiologie.

Also the writings of Gerber, Carpenter, Todd and Bowman, and many others, scattered in various journals.

Although some of my own observations are but repetitions of some recorded by these men, yet that the subject may be the more complete, and as I was then ignorant of them, I have thought best to record the whole.

We see by this that epithelium exists wherever there is mucous membrane, but that it is also found where the former is not.

It may be divided into three varieties, known for some time as the—1st, pavement; 2d, the cylinder; and 3d, the ciliated epithelium. Viewing an epithelial cell as the representative of a species (and it has under *all* circumstances the same characteristics, sufficient to entitle it to the name, and cells have *their* types as well as the higher organizations), the two second forms may be considered as mere varieties or transitionary forms of the first, or pavement, since they arise from it, and only progress to little farther and varied stages of development.

As I have had the pleasure of being able to study all of these forms, as to their origin, development, and their assumption of the peculiarities which distinguish them as varieties, I shall take up each separately.

1st. *Pavement Epithelium.*—This is the simplest form of this structure, and lines the most delicate surfaces belonging to the economy, besides forming the epidermis. It is found upon serous and synovial surfaces, lines delicate tubes, and covers some portion of the alimentary canal. In fact, it occupies all secreting surfaces. This epithelium consists of spheroid cells, of a size varying from $\frac{1}{3000}$th to $\frac{1}{2000}$th of an inch in diameter; each have a roundish, oval nucleus, which is a hollow sphere, and inside of which is sometimes a nucleolus. Situated upon the *primary membrane*, from which they appear to grow, they seem bound together by a most delicate tissue. From such contiguity, and from equilateral pressure, hexagonal and other forms are produced.

The early formative stages of all epithelium are the same, and as the tesselated or pavement variety is of all the simplest, I shall, of course, in describing its origin, give at the same time the different phases of early growth through which the other two forms likewise pass.

The earliest stage of development that I have been able to see in this structure, is a spheroid "bud" standing off the primary membrane. This is the embryo-cell, and may or may not contain a nucleus.

By the function of endosmosis its nutrition goes on, and it gradually enlarges, still preserving its spheroid shape, and its attachment to the *membrane.*

All this time, during which the cell is arriving at its adult and perfect state, and just ready to discharge its function as an individual cell, the nucleus is increasing and assuming more and more the characters of its parent. From a mere dark point in the centre of the parent-cell, it enlarges by endogenous growth, and soon is a hollow vesicle like its parent, but is filled with *a granular* fluid. But the contents, before being granular, are clear and hyaline; so that the first is the *hyaline* stage, and the second the *granular* stage. From this granular liquid, and making the third stage, a nucleolus is formed, but by a method which I was unable positively to determine.

Sometimes two nucleoli are formed in one nucleus; and such phenomenon cannot, I am well assured, be considered accidental, but as having a positive relation with the reproduction of cells, as will soon be made evident.

Most commonly, by the time this *nucleolus* has appeared *as a vesicle*, the parent-cell disappears; so that the occurrence of nucleolated cells in the field of observation is not very frequent. Henle affirms that he has never or quite rarely seen nucleolated cells of epithelium, except in the lower vertebrata.

The parent-cell bursting and discharging its contents, and these contents form the various secretions—the nucleus, being generally unattached to the cell-wall, is set free—and thus freed, it is a true nucleated cell. Whether it then attaches itself to the primary membrane, and then follows the same course as did its parent, is a point which I have been unable to determine. A new cell-bud immediately succeeds the place of the old one just passed away, and passes through the same phases. There is, therefore, a continual death and reproduction of cells, each of which has an individual existence like any of the compound organizations, and which, having completed, they die. The aggregate of these existences, in certain localities, constitutes, in most cases, a certain function in the economy.

For the sake of conciseness and future reference, we will divide the life of these cells into the following well-marked epochs:—

1st. A cell-bud as a hollow sphere, containing a clear liquid.

2d. The clear liquid of this "bud" has a nucleus as a dark point.

3d. This nucleus is a vesicle having a clear hyaline liquid.

4th. The original cell still larger, the nucleus having a *granular* liquid.

5th. An adult cell, whose nucleus has a nucleolus as a point.

6th. Death of parent cell, with a discharge or retention of the nucleus.

Such constitutes the whole biography of cells of epithelium, under most circumstances, and as they are commonly observed; and it will be seen that the general outline corresponds with that of other cells as already observed. The peculiarities here, however, as well as others quite as important connected with their reproduction, deserve our special attention sufficient for another and future separate section.

Cylinder Epithelium.—This, as its name implies, is composed of cells of a cylinder-like shape, though as to exact resemblance, being more like a cone reverted. These cells are attached to the primary membrane by their small or caudate extremity, their broad or vase-like portion floating free. This free extremity is sometimes convex or concave, and sometimes truncate. This form is found, as far as I am aware, upon the mucous membrane alone; and from my own observations, is rarely seen except upon those of the alimentary canal of the vertebrata. It appears to be only the tesselated form modified by a further development;* for like that form, it arises from a primary membrane in the shape of small spheroid cells, nucleated, &c. These increase to a certain size, and then begin to gradually elongate, and this elongation taking place at

* It would appear to be a law among cells of an organizable capacity, or as individuals by themselves, that the more they depart from their true spheroid cellular character, and assume other shapes, the higher may be considered their development.

the expense of that portion attached to the membrane, it necessarily becomes fusiform.

The length of this caudate portion varies much: thus, upon the mucous membrane of the digestive tube the cells are simply pyriform, while those from the bladder have, as may easily be seen, often a tail three or four times the length of the cell proper.* The nucleus and nucleolus of this variety in no way differ from those of the pavement or simplest form just described. As for its more special localities, it would be rather difficult to define them accurately. It occupies mucous membranes only, and generally those which act as large aperient ducts. Rarely is it found investing parts, having the functions of peculiar secretions, and it is in this way that it differs physiologically from the pavement form.

Ciliated Epithelium.—This is the third and last variety—and, aside from the phenomena which invest it in common with the other forms with great interest, it has others of the most curious and remarkable in physiology. We will therefore give it a detailed and special attention.

Its marked anatomical feature is that one or more of the surfaces of the cells (which may be of a pavement or cylinder form) are covered and studded with digitoid elongations of the cell-sac, known better, perhaps, by the name of *cilia.* Henle represents the ciliated epithelium as belonging to the cylinder form only; but my own observations have shown that, although generally of the cylinder form, it may often be found, especially when taken from the human mouth, or from those of the Batrachians, to be of the pavement variety. Its origin and simple cell characteristics need not detain us; for, previous to the formation of the cilia, it has no distinguishing traits.

The production of these cilia I have had the good fortune to observe—the observations being made upon the epithelium of some of the Batrachians.

It takes place in the following manner: The cells having reached the adult age (for I have seen no *young* cells with cilia), there appears upon its free extremity a vesicular projection, which, when fully formed, rests like a cap upon its surface.

This then splits up into fasciculi, which, being sub-divided, form the true cilia.†

The cilia are therefore situated upon the extremity alone of the cell, if the cell be of a cylinder shape, and upon a certain segment if the cell be spheroid.

Generally speaking, they stud thickly the surface, but I am quite positive

* The extreme caudate character of many of the epithelial cells of the bladder is a fact worth the remembering, in a pathological as well as physiological point of view. For with those not accustomed to observations of this kind, the appearance of such cells in urine would be a matter of much surprise. At first they might seem to be spermatozoa, then again the caudate cells of encephaloid carcinoma.

† Kölliker, in a work published in 1840, has noticed, as I have since found, a similar mode of their production in the cells of the oviduct of *Planorbius corneus.*—Vid. Beitraege Zur Kenntniss der Saamen fluessigkeit wirbelloser Thiere." p. 33.

in affirming that in some few instances I have seen them situated coronet-like around the edge, the middle portion being unoccupied. In such cases no new mode of formation is involved, since such a disposition would ensue, if the parent vesicle had become concave before the division into fasciculi.

The structure of these cilia has been much commented upon by Ehrenberg, Purkinjo and Valentin, and, as far as concerns those of epithelial cells, has had an undue share of importance. They speak of them as being bulbous at their lower extremity; but although my own observations on this point have not been sufficient to afford me an opinion, yet their very mode of formation seems to argue against such view, and indicate that they differ in no way from the cell-wall on which they stand.

Ciliary Motion.—The most interesting and the most difficult part of our subject appear together; and one cannot leave this field of inquiry without having many new views of animal powers and forces. The motion of entire cells cannot fail to excite our attention, but the movement of appendices to cells, when a certain and definite system of motions is performed, is one of the most interesting points in physiology.

We are here at once brought back to our simplest ideas of motion, and where the fact does not suggest a complication, as in the higher forms, but where the relations of the body or bodies to space is most simple, because the power acts most probably in a direct manner. It is on this account that I shall treat this portion of our subject with more than ordinary detail.

The cilia of epithelial cells seem to have two kinds of motion only. 1*st.* A moving or fanning motion, which when slow is very uniform; but when rapid, assumes a kind of dancing character. This is the most common movement seen. 2*d.* A twirling rotatory motion of the lower portions of the cilia, being infundibuliform. Of whichever of these the motions may be, they are always uniform throughout the same cell; thus indicating that the cause acts equally throughout.

We know as yet really nothing about the essential nature and cause of animal motion. We may divide and subdivide the powers by which it is expressed in the higher forms, but inevitably fall upon the last material mechanism through which it is produced, and can go no further.

The ideas of muscular or an allied tissue and those of animal motion have appeared almost inseparable in physiology; and this because animal actions have always, or nearly always, been traced to such tissue; and where, in some of the lower forms, its direct demonstration could not be made, its presence has been assumed in virtue of necessity. But it seems to have been forgotten that, as in the external world, the same results follow from the employment of dissimilar means, or *vice versâ,* so in the domain of physiology, we often have the same function performed by dissimilar organs, and *vice versâ.** We can, therefore, consistently with analogy, look for real motion from other

* Strauss Durckheim.

than muscular tissues, and I have no doubt that further and more accurate researches into the infusorial world will lead us to adopt views of this kind.

This digression may serve as a fitting prologue to the following and most difficult part of our subject.

Ordinarily, ciliary motion may easily be observed, but few are aware of the difficulties which prevent a true solution of the problem of its cause. The first step in an inquiry of this kind is to ascertain how far we can consider these muscular movements.

It is well known that Ehrenberg has affirmed to have seen bulbous roots of the cilia of some of the infusoria, and thinks that these bulbs contained the small muscles by which these bodies were moved. But although bulbous cilia may have been seen, yet the assertion of the muscular contents is quite gratuitous, as it is based upon the idea that their motion must be of muscular origin.

Purkinje and Valentin afterwards thought that the cilia of epithelial cells are bulbous; but as would be but justice to the optics of the time at which their investigations were made, they are far from being positive on this point. The grounds for not adopting the opinion of their muscular cause become more numerous and positive as the inquiry proceeds.

In the first place, the relative size of the cilia to that of the muscle makes it inadmissible, for in the vertebrata the cilia of cells are very much smaller than the smallest fibrillæ of muscular tissue; so that, if the moving tissue be muscular, it is different from that of the body generally. To the same effect is also argued by the primitive formation of muscular fibrillæ—being chains of cells, nearly as large as those of ephithelium themselves.

The followers of Ehrenberg would perhaps affirm that these are no objections, since that great microscopist has mapped out whole systems of internal organs in animals equally as small. Be this as it may with Ehrenberg, other observers upon this subject have arrived at the conclusion that the difficulties of observing clearly and accurately matters so extremely minute, with the microscope, must ever cause an unfortunate obscurity to exist upon this and all kindred subjects.

There are, however, other objections of more determinate value.

The motion of the cilia belongs to the cell alone, and has no connection with the system to which the latter is attached. This is at once demonstrated by their long-continued movements, when the cells are swimming free in the field of view. We know as yet no muscular tissue which has not nerves, and one cannot for a moment suppose that these cells have a nervous tissue.

Some experiments instituted by me upon the epithelium of some of the Batrachians have all tended towards the same point.

I killed a frog, and wrapping it in a damp cloth, laid it aside for sixteen hours. At the end of that time, I found the cilia of the epithelial cells of the throat in active motion. At the end of forty-eight hours, the motion had not ceased, although the animal had so far decomposed as to be offensive.

These experiments were repeated with the same result, and in one instance I think the motion was continued for a considerably longer time. At least it appeared that the motion could be kept up long after the animal, and even the primary membrane, had begun to decompose; and that they always were present until the death and disruption of the cell to which they belong. And from this it would appear that they are inseparably connected with the life and functions of the cell.

The effect of physical agents upon these movements should not here be omitted.

Ether, as is now well known from a modern discovery, when inhaled and distributed throughout the system, first paralyzes the muscles of animal, and lastly those of organic life; and when this last occurs, death of course follows.

In my own experiments with this agent upon some of the lower animals, I have found that if the etherization be sudden and fatal, the post-mortem muscular irritability of the animal is either very much impaired or entirely destroyed; in other words, the shock which the nervous system thereby receives is so great as to destroy essentially most of its inherent energy and susceptibility to the action of external agents.

With some frogs, which I suddenly and fatally etherized—and whose organic life seemed thereby so completely destroyed that irritation would not produce any muscular excitation—I found that the motion of the cilia of the epithelial cells upon their mucous membrane was not in the least impaired by such experiment, and their duration was equally as long as those of cells coming from animals otherwise killed.

The narcotico-acrid poisons seem to have as little effect; for with an animal which I destroyed with strong hydrocyanic acid, there appeared no change in the movements of the cilia.*

It would be supposed that the effect of electricity upon these bodies would be productive of results tending to throw some light upon the nature of the moving power, since we are now so well acquainted with its usual effect upon all known contractile tissues.

With a view to learn definitely the effect of this agent in this respect, I made the following experiments:—

A frog was taken, and being rendered insensible by ether, one needle was inserted into the brain and another into the lower portion of the spinal cord. A powerful electro-magnetic shock was then passed through the animal, the wire touching the two points. The animal was instantly killed. An immediate examination of the epithelium upon the mucous membrane showed the motion of the cilia to be unaffected.

Not satisfied with this experiment, I took another frog; and, after etherization, inserted two needles opposite each other, just under the mucous mem-

* Purkinje and Valentin speak of having tried strychnia with the same effect.

brane of the pharynx; a powerful shock was then given; an immediate examination of the cilia showed them in active motion.

To make the matter still more certain, I took another frog, and dissected up a quadrilateral strip of the mucous membrane of the pharynx. The needles being insulated from the rest of the animal were inserted oppositely. A charge was then sent through it, but the motions of the cilia were not affected.

Lastly, I took another frog and removed from its mouth a portion of the epithelial layer. This was placed upon a plate of glass in water, and then put under the microscope, and, while I was observing the motions of the cilia, an assistant applied the two poles of an electro-galvanic battery at the opposite ends of the glass in the water. A charge was then transmitted, but all the while the motions of the cilia were not in the least perceptibly affected. These various experiments were repeated, but with the same results; and in all of them great care was taken that no means of delusion should be introduced.

It would therefore appear from the above, that whatever may be the moving power of these cilia, their motion, unlike that produced by all other contractile tissues with which we are acquainted, is unaffected by electrical agents.

We again revert to the question, *What is the cause of ciliary motion?* Let us sum up the arguments which go for its exclusion from the muscular domain.

1*st.* It appears that the power belongs to the cell, considered as an individual organism.

2*d.* That the motion is capable of continuing until the death of the cell, it matters not what changes occur in the animal body to which they belong.

3*d.* That the motion is unaffected by any method by which the animal to which they belong may die.

4*th.* That electrical forces, to which the other contractile tissues have so great a susceptibility, do not in the least affect the continuance or variety of their motions.

5*th.* That all acids which, when directly applied, impinge upon the tissue of the cells, destroy rapidly the movements of their cilia.

Now, if we bear in mind these results, and at the same time the fact that as yet no muscular structure has been distinctly seen in these bodies, and that they are known to exist on the ova of polypes, which in one sense are structureless—these points being considered, one is perhaps justified in dissenting from the opinion of Prof. Ehrenberg, that they are the result of muscular tissue.

With such a negative view, I am quite unwilling to offer any positive opinion, more especially when I reflect how little we know concerning the cause of motions in the lower and infusorial world.

Voluntary motion has been considered the peculiar feature of the animal world, and the distinguishing characteristic which separates it from the vegetable kingdom. But the whole matter is now just as vague as before this feature was introduced. For it now remains to be decided what constitutes voluntary motion—a question not yet ripe for decision.

If we consider that among the higher animals, a voluntary motion consists mainly, 1st. In a sensation being perceived; and 2d, a consequent action; then certainly we cannot regard the "adapting" motions of the members of the lowest animal world, scarce escaped from the characteristics of maternal cells, as voluntary, when their organization admits of none of the usual sentient organs.

Take any species of the class *Rotatoria* of Ehrenberg, and observe its motions beneath a microscope; they are not molecular, nor oscillatory, but have a certain indistinct adaptation to existing circumstances. Such motions are wrongly termed voluntary, and although they seem somewhat different from those of the *Oscillatoria* of the vegetable world, yet most probably belong to the same category. To the same belong the movements of spermatic particles which are only epithelial cells of a peculiar animal character,* and fulfilling a higher function than that usually allotted to these cells. The spermatic particles exhibit the same phenomena as to motion as do the cilia of the epithelial cells, under the same experiments above instituted; and as a variety of epithelial structure, it would have claimed our special attention were it not too long, and already the subject for a future discussion.

Exactly as the movements of the cilia cease with the life of the epithelial cell, so do the motions of spermatic particles cease with their vitality.

All these epithelial motions have not the least claim to that of a voluntary character, although often remittent in their course. All that the foregoing inquiries and experiments have shown, are only negative in character; and for positive knowledge of the cause of ciliary motion, we probably shall never have it until we know more extensively and clearly the laws of vitality as manifested in primordial organic forms. However this may be, the following conclusions can, I think, be justly drawn from the foregoing remarks.

1*st.* If the movements of the cilia of epithelial cells are due to a contractile tissue, at their lower portion, this tissue is unlike any other contractile tissue of the animal economy with which we are acquainted.

2*d.* We have no reason to suppose this tissue to be muscular.

3*d.* Because of the relative size of the fibrillæ to that of the cilia, and of the absence of nerves.

4*th.* Because also electrical agencies do not affect it.

5*th.* We cannot consider this contractile tissue of the nature of that of the dartos.

6*th.* Because the movements of the cilia are of a uniform and rhythmical character.

7*th.* That these movements are inseparably connected with the life of the cell to which they belong, considered as an individual organism.

8*th.* That these ciliary movements of epithelial cells are, in many respects,

* This I am persuaded, from observations in this direction, which have of late quite closely engaged my attention, and which I shall expose at another time.

analogous, if not identical, with those of many of the infusoria, and also with those of the ova of polypi.

9th. That after a full consideration, one would be inclined to the opinion that ciliated epithelial cells (spermatic particles included), although belonging to the category of individual animal cells, differ widely from cells in general, and especially as exhibiting a higher form of vitality and function.

Reproduction of Epithelial Cells.—While speaking in the foregoing pages of the growth of epithelium, I merely alluded to its reproduction by the usual endogenous cell method, viz., by nuclei growing into cells. It would have then been in order to have closed up all that which relates to this part of the subject; but as it might obscure the description there given, and more especially as it seemed to demand a separate paragraph from peculiarities, I shall here take it up as a distinct portion.

The earliest period at which we can observe, the future cell is a minute granule in a blastema. As to the origin of this, we know really nothing. Next, it is observed as a hollow vesicle, filled with clear fluid. Still further, this liquid is cloudy and granular. Next, the granular appearance has disappeared and a solid nucleus is seen. All this while the parent cell is increasing, and at this period you have a nucleated cell. This nucleus goes through the same changes as its progenitor; and when it has a nucleus, we have a nucleolated cell.

It will immediately be seen that the mode of cell formation here indicated is quite different from that advanced by Schwann and Schleiden as to both animal and vegetable cells. It is important, therefore, on this very account, marking a more extensive mode of their production. But its great interest lies in another direction, as showing the real grounds of the identity of the character of a cell and that of an ovum.* An ovum, we know, is but an agglomeration of peculiar cells, for the highest end attainable by cells in the animal economy. Our simplest and most divested idea then of it, is a peculiar cell, and the changes here spoken of relate to the real value of this peculiarity.

I have spoken of spermatic cells as being really epithelial cells. Now, between the true structure of an ovum and that of a cell there is no dividing line among the lower animals; and we can only decide the character of each by the products (ova or sperm) which each yields. In these cases, the ova are first cells upon a basement membrane of the ovarian tubes, and except for a few peculiarities, do not differ from the sperm cells originating in the same way. Ova are therefore originally but epithelial cells. It can therefore be no wonder that the formation of epithelial cells upon mucous membranes should thus so thoroughly agree with the formation of ova.

Prof. Agassiz was the first, I think, to point out these changes as occurring in the ovum. This he did in the spring of 1848.

* Vid. a paper on this subject, in proceedings Am. Associat. for Prom. of Science, 1849, p. 261.

His observations were made upon some of the inverbetrata, and upon the ova in their earliest stages, viz., as primitive oval cells. I need not here detail them; the same phases are passed through exactly as those just indicated with epithelium. The peculiarities, then, of ova, or more properly of ovarian cells, lie not in their origin and mode of endogenous reproduction, but in their capacity for a destined and invariable end; viz., the reproduction of a new individual being.

Another mode of the increase of these cells, and which I have repeatedly seen, must not here be omitted, especially as it is in corroboration of the above views.

Out of the granular contents of the nucleus of a cell, there sometimes appear two nucleoli, instead of one. These are generally not near each other, but at opposite extremities of the nucleus, which is then oval.

Soon after this, a slight sulcus is perceived at one of the poles of the transverse diameter of the nucleus. This deepening, the single nucleus becomes finally divided into two. So that from one nucleus of a parent cell, two nuclei may occur, each of which has its nucleolus.

This mode of increase by fissuration corresponds exactly with the multiplication of the vitelline cells in the ovum. So that the mode of increase of the ovum cannot, as has heretofore been done, be considered as peculiar, but as belonging to those same laws which seem inherent in all single, non-organizable cells.

Functions of Epithelium.—The *elaboration* from the blood of the special fluid of the animal body, known properly by the name *secretions* (not *excretions*), is performed, it would appear, by the agency of cells; and our best anatomical as well as physiological idea of the organs performing these functions, is a tissue or tissues, so arranged or disposed as to afford the largest surface for the existence of cells. These organs are glands proper, and the cells elaborating these secretions are epithelial cells.

Saliva, milk, gastric juice, pancreatic fluid, bile, synovia, spermatic fluid, the secretions of the vascular sanguineous glands—as the thymus and thyroid glands and suprarenal capsules—the various secretions of serous cavities, all owe their peculiarities to the particular elaborative action of the cell walls through which they are obliged to pass before discharged. These are but the combined contents of ruptured epithelial cells.

All these glands mentioned seem to be but a combination of the more solid or basement tissues for the support of what are called gland-cells, which completely line their internal surfaces. These gland-cells, have no distinctive characteristics from true epithelium.

Many of the most difficult problems in physiology here come in and demand a consideration. One of which is, why that the epithelial cells of the mammary gland should secrete milk, while those of the cryptic glands of the stomach should secrete gastric juice. Such inquiries as these belong to

the highest domain of the science, and cannot be solved until we shall have become more thoroughly acquainted than we now are with the powers and properties of animal cell-membranes, considered as to their two inherent and permanent capacities, endosmosis and exosmosis.

It is thus that all our investigations upon cell-origin and development are continually shedding new light upon our vague ideas of what constitute the bases of all physiological science.

From what we have just said, let us see what constitutes our simplest idea of secretion. A single cell receiving by endosmosis into its interior the serum of the blood, and by this means elaborating its special character.

The function of *eliminating* effete matters from the blood does not most probably, I think, in the most marked instance we have in the body, belong to the agency of cells. This is the excretion of urine. Although we find the tubulæ uriniferi lined even to their termination with epithelium, yet my own microscopical analysis of these organs has led me to infer that this excretion must be viewed as a direct transudation from the blood into these tubes, in the Malpighian bodies. The functions of these last-named bodies cannot, I think, be otherwise satisfactorily explained in accordance with their anatomical relations. A considerable quantity of the water belonging to the urine may, perhaps, be derived from the escaped contents of ruptured epithelial cells lining the tubuli. But this watery fluid has probably no characteristics, and is like that from the same source, bathing serous membranes. And all that which distinguishes the urine as such, belongs to the functions of the Malpighian bodies. This portion of our subject, however, needs a further analysis.

The production of spermatic particles and of ova, although forming a part of this subject, as we have seen, cannot here be discussed. Their origin has been truly spoken of. But of themselves, they have important points and relations sufficient for a separate article.

The importance of the epithelial structures in the animal economy, and the high relations which they sustain, have thus in the foregoing pages been imperfectly delineated.

The subject is far from being as yet exhausted, in a physiological point of view; and as pathology is but an erratic physiology, so I am well assured that we can look at the former oftentimes for a fine elucidation of the true bearings of the latter, as far as relates to this tissue. But details of this character would scarcely belong to a purely physiological paper, and are therefore in this place omitted.